SEASONAL DISTRIBUTION OF STELLER SEA LIONS (*EUMETOPIAS JUBATUS*) IN RELATION TO HIGH-QUALITY EPHEMERAL PREY SPECIES IN SOUTHEASTERN ALASKA

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SOUTHEASTERN ALASKA

A

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By

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ABSTRACT

Energetic demands are high for sea lions during spring when females are pregnant and lactating and males are preparing for extended fasting during the breeding season. Therefore, I predicted that the distribution of sea lions in spring would be influenced by the distribution of spring-spawning aggregations of high-energy Pacific herring (*Clupea pallasii*) and eulachon (*Thaleichthys pacificus*) in southeastern Alaska. Monthly aerial surveys at 23 Steller sea lions haulouts revealed that haulout use was seasonally dynamic. Some sea lion haulouts were only occupied during spring. Other haulouts exhibited pronounced increases in the number of sea lions during certain seasons. Sea lion haulouts with peak numbers of sea lions in spring were significantly closer to forage fish aggregations than haulouts with peak numbers of sea lions at other times of year. From March through May 2002, I used aerial surveys to monitor the number of Steller sea lions at spring spawning aggregations of Pacific herring and eulachon. The maximal numbers of sea lions observed were 949 at a eulachon-spawning site and 252 at a herring-spawning site. Seasonal pulses of high-energy food resources may be critical to the reproductive success of individual Steller sea lions.

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INTRODUCTION[1]

The distribution and abundance of a species is influenced by abiotic and biotic factors of the environment, including the distribution and abundance of predators and prey (Andrewartha and Birch 1954). These factors often change seasonally, given the changes in the physical and biological environment that a species inhabits (MacArthur 1972). Prey resources that occur seasonally at predictable times and locations may be especially important to predators. Seasonally aggregated prey resources can influence timing of breeding cycles, reproductive rates, body size, group size, and distribution of predators (Payne *et al.* 1986; Hansen 1987; Mehlum *et al.* 1996; Ben-David 1997; Hilderbrand *et al.* 1999; Holekamp *et al.* 1999; Skov *et al.* 2000; Swartzman and Hunt 2000; Heyman *et al.* 2001; Blundell *et al.* 2002). For most mammalian species, body condition is critical during the energetically demanding phases of breeding and lactation (Robbins 1983; Gittleman and Thompson 1988), and the availability of aggregated high-energy prey at times of high energetic demands may be critical to reproductive success of predators.

Pinnipeds depend upon the marine environment for foraging, and they use terrestrial sites for birthing, caring for young, resting, and avoidance of predators (Bartholomew 1970; Bonner 1984). Life-history strategies vary along phylogenetic lines within the pinnipeds. The period of offspring dependency ranges from a few days to two months in the Phocidae and from several months to three years in the Otariidae (King 1983). Differences in the length of the lactation period and offspring dependency among

[1] Manuscript prepared for submission to Marine Mammal Science. J.N. Womble, M.F. Willson, M.F. Sigler, and B.P. Kelly.

pinniped species are probably related to the amount of energy that each species is able to store prior to parturition (Costa 1991a, 1991b, and 1993). The longer lactation periods of otariids require females to alternate foraging trips to sea with nursing bouts on shore (Oftedal *et al.* 1987). The prolonged lactation period favors foraging close to the terrestrial site where the dependent pup is located. Thus, most otariids and some phocids are central-place foragers (Orians and Pearson 1977) while their pups are land-bound.

Steller sea lions (*Eumetopias jubatus*) are temperate-zone otariids, ranging throughout the North Pacific rim (Scheffer 1958). The breeding and pupping season occurs from mid-May to the end of July, depending upon location (Pitcher and Calkins 1981). Steller sea lion males arrive at rookeries in early May to establish territories. Once territories are established, male sea lions may stay at these sites from 20-68 days without leaving to feed (Thorsteinson and Lensink 1962; Gentry 1970; Sandegreen 1970; Gisiner 1985). Steller sea lion females give birth to a pup in early June (Pitcher *et al.* 2001) and remain ashore with their pup for 5-13 days after parturition before the first foraging trip to sea (Sandegreen 1970). Foraging trips continue throughout a protracted lacation period that averages 330 days and, in some cases, extends to three years (Gentry 1970; Sandegreen 1970). Pups begin to accompany their mothers on foraging trips as they get older (Gentry 1970; Sandegreen 1970); however, it is likely that females still return to haulout sites to provision their pups.

Productivity in the marine environment is seasonally dynamic (Laws *et al.* 1988), and seasonally predictable aggregations of prey, such as densely aggregated spawning fish, may provide an important concentration of energy-rich prey for predators.

Anadromous Pacific salmon (*Oncorhynchus* spp.) are energy-rich anadromous fish that return to spawn in rivers along the north Pacific rim (Groot and Margolis 1991), attracting numerous avian and mammalian predators (Willson and Halupka 1995; Willson *et al.* 1998; Gende *et al.* 2001). Also important in the diet of Steller sea lions are other energy-rich fish, such as Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), northern lampfish (*Stenobrachius leucopsarus*), and eulachon (*Thaleichthys pacificus*). All of these fish species occur seasonally in the diet of Steller sea lions in Alaska (Pitcher 1981; Merrick *et al.* 1997; Sinclair and Zeppelin 2002; Winship and Trites 2003), but little is known about their life history, spawning patterns, and distribution in Alaska with the exception of herring (Rounsefell 1930; Rounsefell and Dalgreen 1935; Carlson 1980). These seasonally abundant, energy-rich forage fish are critical to the biology of many predators (Springer 1992; Byrd *et al.* 1997; Skov *et al.* 2000; Bishop and Green 2001; Litzow *et al.* 2002; Marston *et al.* 2002; Rodway *et al.* 2003).

While there have been several observations of pinnipeds aggregating at concentrations of forage fish in the north Pacific (Table 1), no studies have specifically addressed the possible ecological importance of ephemeral concentrations of energy-rich prey fish as it relates to pinniped life-history strategies. Spring spawning aggregations of forage fish may be important to Steller sea lion ecology for several reasons. First, spring spawning aggregations occur in relatively predictable sites and at a time of year when energy demands are high for sea lions. Second, herring and eulachon are high in lipid content and energy density (Table 2) and are densely aggregated at spawning time.

Third, energetic demands are high for sea lions during spring when females are pregnant and lactating and males are preparing for extended fasting during the breeding season (Winship *et al.* 2002; Winship and Trites 2003). Therefore, spawning aggregations of forage fish may be of substantial seasonal significance to the nutrition and energy budgets of sea lions during a critical part of their reproductive cycle, when energy demands are at a peak. If spring-spawning forage fish aggregations are important to the reproductive ecology of Steller sea lions, it should be reflected in the spatial distribution of sea lions in spring. Thus, given the seasonally dynamic prey environment coupled with the protracted lactation period of Steller sea lions, I expected 1) that sea lions would use terrestrial haulout sites seasonally, depending upon the availability of seasonally abundant prey species near those haulout sites and 2) that the distribution of Steller sea lions during spring (March–May) would be influenced by the distribution and abundance of spring spawning herring and eulachon aggregations in southeastern Alaska.

The objectives of this study were to provide insight into the seasonal foraging ecology of sea lions by 1) determining the seasonal distribution of sea lions at haulouts, particularly in spring, 2) documenting the numbers of sea lions at spring spawning aggregations of herring and eulachon in southeastern Alaska, and 3) relating the distribution of sea lions to herring and eulachon aggregations. Specifically, I tested the following hypotheses against the null hypotheses of no effect.

1) Haulouts with peak numbers of sea lions in spring are closer to herring and eulachon aggregations than haulouts with peak numbers at other times of year.

2) The number of sea lions at haulouts in spring is inversely correlated with minimal distance to herring and eulachon spawning aggregations.

3) The number of sea lions at haulouts in spring is correlated with the number of herring and eulachon spawning aggregations within a limited radius.

4) The number of sea lions observed at spawning aggregations of herring and eulachon is correlated with the estimated density of spawning herring and eulachon.

METHODS

Seasonal Distribution of Steller Sea Lions: Monthly Aerial Surveys

Steller sea lions at 23 haulouts in the northern portion of southeastern Alaska (Figure 1) were counted from an airplane monthly from March 2001 through July 2002 to assess seasonal distribution and use of haulout sites. Surveys were conducted from a Cessna 206 amphibious airplane with an experienced survey pilot between the hours of 1000 and 1600 (Withrow 1982) and, when possible, within 3 hours of low tide. The observer-photographer sat in the front right seat and photographed sea lions on shore through an open window from an altitude of 250 meters at a speed of 183 – 210 kilometers per hour.

Photographic slides of haulouts were taken using a 35mm auto-focus camera (Nikon 8008S) with a motor drive equipped with a 70-210mm zoom lens and a 35mm auto-focus digital camera (Nikon D1X) equipped with a 70-300mm zoom lens. Color slide film (Fuji 400 ASA and Provia 400 ASA) was used at a shutter speed of 1/500 of a second. The time, date, location, and roll and frame numbers were recorded for each photographed haulout. Overlapping photographs were taken if more than one photograph was needed to cover sea lions at each haulout.

Haulout sites at Eldred Rock, Tlingit Point, Venisa Point, Sisters Island, Pinta Rocks, and False Point Pybus were omitted after no sea lions were observed for 12 consecutive surveys. Anecdotal reports suggested that some of these sites may have been used in the past; however, they appear not be used on a regular basis.

A local film-processing firm developed photographic images and each slide was labeled with date, location, roll number, and frame number. The clearest image was projected onto a white piece of paper, and each sea lion was marked and counted twice by an experienced counter using a hand-held tally counter. Digital photographic images were stored on Lexar media cards (128 MB) and later downloaded to a computer. The clearest digital image of each group was imported into the geographic information system software, ArcView.

Number of Steller Sea Lions at Spring-Spawning Fish Aggregations

From March 21, 2002 through May 15, 2002, sea lions were counted at spring spawning aggregations of Pacific herring and eulachon (Figure 2). Sea lion haulouts and Pacific herring and eulachon spawning sites in the study area were surveyed between 1000 and 1600 hours at approximately 10-day intervals. At spawning aggregations of herring and eulachon, transects were flown parallel to the shoreline approximately 200 meters offshore. For eulachon spawning sites, I surveyed the entire shoreline of the estuary/bay associated with the river where eulachon spawn. For herring, the entire shoreline associated with herring spawn was surveyed. When sea lions were detected beyond 200 meters, the pilot deviated from the transect. I assumed fish were present if I observed 1) commercial and/or subsistence fishing activity, 2) fish schools, 3) spawn/milt on the surface of the water (for herring only) or, 4) presence of avian predator aggregations. Aerial surveys in the Yakutat forelands were conducted by U.S. Forest Service (USFS) personnel and were conducted using the same aerial survey protocol.

Geographical Ecology: Geographical Information System (GIS) Database

To synthesize the geographical ecology of Steller sea lions, herring, and eulachon, all known current and historical sea lion haulouts in southeastern Alaska were compiled from published and unpublished reports (Rowley 1929; Imler and Sarber 1947; Mathisen and Lopp 1963; Calkins and Pitcher 1982;[2] Loughlin *et al.* 1984; Bigg 1988) as well as from local observers. Location and timing of herring and eulachon aggregations were obtained from Alaska Department of Fish & Game, USFS biologists, and subsistence users. These data were compiled, incorporated into a database, and imported into Arcview. A GIS map was created with the following coverages: 1) Steller sea lion haulouts (Figure 1), 2) herring spawning locations, and 3) eulachon spawning locations (Figure 2).

The GIS database was used in conjunction with ArcView 3.2a to determine the distance between Steller sea lion haulout sites and Pacific herring and eulachon spring-spawning sites. In particular, I determined the following:

[2] Calkins, D.G., and Pitcher, K.W. 1982. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Outer Continental Shelf Environmental Assessment Program United States Department of the Interior Bureau of Land Management. Final Report: Research Unit 243 Contract #03-5-022-69.

1) Swimming distance from sea lion haulouts to the closest forage fish spawning aggregation.
2) Number of forage fish spawning aggregations within 10, 20, 30, 40, 50, 60, 75, 100, 125, 150, and 195 kilometers of a haulout.

Seasonal Haulout Classification

The seasonal use of haulouts was determined by examining the monthly counts of Steller sea lions. I classified haulouts according to seasonal patterns of occupation. A peak in number of sea lions was defined as a count that was at least 80% of the maximal count of sea lions at a haulout. At some haulouts, a peak occurred in more than one season and haulouts with this pattern were classified as having two peaks (*i.e.* spring/fall peak). Seasons were defined as winter (December-February), spring (March-May), summer (June-August), and fall (September-November). The haulout classifications were:

Spring Peak Haulout: peak numbers of sea lions occurring during spring;

Spring Ephemeral Haulout: only occupied by sea lions during spring;

Spring/Fall Peak Haulout: peak numbers of sea lions occurring in spring and fall;

Summer Peak Haulouts: peak numbers of sea lions occurring during summer;

Fall Peak Haulouts: peak numbers of sea lions occurring during fall;

Fall Ephemeral Haulouts: only occupied by sea lions during fall.

Fish Density Estimation

Herring biomass was determined from spawn deposition surveys in areas where commercial herring fisheries were monitored during the spring spawning season of 2002.[3] The spawn deposition methods combined SCUBA diver estimates of herring egg deposition, estimates of total area receiving spawn, and average fecundity to derive an estimate of herring spawning biomass.[4] Currently there are no area-wide biomass estimates for eulachon in southeastern Alaska; therefore, an index for eulachon biomass was developed. A digital elevation model was used to measure the watershed area from below 100 feet in elevation to mean low tide at each eulachon spawning drainage in southeastern Alaska. The area measurement was used as an index of spawning habitat available to eulachon, and the index of spawning habitat area was assumed to be related to the abundance of eulachon in a river.

Statistical Analysis

Data were log-transformed when they did not meet equal variance and normality assumptions of analysis of variance (ANOVA) (Zar 1999). The Spearman rank-order correlation coefficient (Siegel and Castellan 1988) was used to determine the association between the maximal number of sea lions and the minimal distance to forage fish aggregations and number of forage fish aggregations within designated distances from sea lion haulouts.

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[3] Unpublished data from Dave Carlile, Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 240020, Douglas, AK 99824, November 2002.

[4] Hebert, K., and D. Carlile. 2002. Southeast Alaska/Yakutat Annual Herring Research Report, 2000/2001 Seasons. Regional Information Report 1J02-36. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska 99801.

RESULTS

Seasonal Distribution of Steller Sea Lions

The distribution of sea lions at haulouts was seasonally dynamic. Some sea lion haulouts were only occupied seasonally, whereas other sites were occupied year-round but with pronounced increases in the number of sea lions during certain seasons.

Spring Peak Haulouts

Haulouts where sea lion numbers peaked only in spring included Gran Point, Met Point, Mist, Sunset Island and Point Lull (Figure 3). Most spring peak haulouts were located within 25 km of the closest spring-spawning fish aggregation (Figure 4). The exception was South Marble Island, located 39 km from the closest spring-spawning fish site in Adams Inlet (Figure 4).

Gran Point, a spring peak haulout located in northern Lynn Canal (Figure 4), had a dramatic increase in the number of sea lions during spring; with a maximum of 1,087 sea lions observed on April 18, 2002, representing a 76% increase from the previous month. Sea lion numbers not only increased at Gran Point, but sea lions also used additional haulout sites, located north and south along the shoreline from Gran Point. The same pattern of dramatic increase in numbers of sea lions during spring also occurred at Gran Point in 1996 and 1997.[5] In addition, Met Point is a sea lion haulout located in northern Lynn Canal that peaks in number of sea lions during spring.

There are six eulachon spawning sites in Northern Lynn Canal, which has one of the highest densities of eulachon spawning sites in southeastern Alaska. Gran Point is the

[5] Personal communication from Kip Kermoian, Haines, AK, November 2001.

northernmost sea lion haulout in Lynn Canal and is near herring (5km), eulachon (8km), and capelin (29km) spawning sites. On April 18, 2002, 2,213 sea lions were counted at haulouts and at fish spawning sites in Lynn Canal, representing 14.5% of the sea lion population in southeastern Alaska.

Spring Ephemeral Haulouts

Four sea lion haulouts (Dorothy, Berners Bay, Akwe, and Dry Bay) were only occupied in spring and were all located within 3-14 kilometers (mean = 6.00 km, SE = 2.67) of a eulachon-spawning site (Figure 4). Two of the spring ephemeral sites are located along the Yakutat forelands and are only occupied between February and May, when eulachon return to spawn. Use of the haulout sites along the Yakutat forelands appears to be associated with the return of spawning eulachon into several river systems (Situk, Ahrnklin, Dangerous, Akwe, Alsek) in the region. The Akwe River and Dry Bay haulout sites are sand substrates and are located at the mouth of the rivers where eulachon enter the river to spawn (Figure 4). At Dry Bay, near the mouth of the Alsek River, 1,347 sea lions were hauled out during April 2002;[6] this is the largest number of sea lions counted at any terrestrial haulout during spring in the study area.

Haulouts located at Dorothy and Berners Bay were also occupied only during spring. Dorothy, located in Taku Inlet, is 14 km from a eulachon spawning site in the Taku River Inlet (Figure 4). A maximum of 283 sea lions was observed at Dorothy on April 18, 2002. On this same date, there were no sea lions observed at Circle Point, the closest sea lion haulout to Dorothy, located 26 km from the eulachon-spawning site in the

[6] Personal communication from William G. Lucey, U.S.D.A. Forest Service, Yakutat Ranger District, P.O. Box 327, Yakutat, AK 99689, May 2002.

Taku River Inlet. On April 10, 2002, 235 sea lions were observed cooperatively foraging at Jaw Point, near Dorothy. Dorothy is located farther up Taku Inlet and is closer to the eulachon spawning area than Circle Point and it is likely that sea lions may move to Dorothy from Circle Point when eulachon move into the area prior to spawning (Figure 4).

Spring/Fall Peak Haulouts

Three of the spring peak haulouts, Tenakee Cannery Point, Benjamin Island, and South Marble Island, peaked in number of sea lions during spring and fall (Figure 5). Benjamin Island is located less than 5 km from a winter herring aggregation.[7] Tenakee Cannery Point is also located 3 km from herring spawning site; however, the closest herring spawning site to South Marble Island is 88 km away.

Summer Peak Haulouts

Although in some cases the distribution of sea lions at haulouts reflected the distribution of spring-spawning fish, haulouts in Frederick Sound were also occupied throughout the year but peaked in abundance during summer, particularly in July and August (Figure 6). The peak numbers of sea lions coincided with the return of pink salmon to the area. All of the haulouts that experienced peak numbers during summer were located in Frederick Sound, with the exception of Graves Rocks, a rookery located along the outer coast near Cross Sound (Figure 7).

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[7] Personal communication from Mike F. Sigler, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11130 Glacier Highway, Juneau, AK 99801, November 2002.

Fall Peak Haulouts

Three sea lion haulouts peaked during the months of September, October, and November (Figure 8). Two of the haulout sites, Rocky Island and Northwest Inian Island, are located in the Icy Strait/Cross Sound region of southeastern Alaska (Figure 9). Large fall runs of chum salmon occur in the Excursion River[7], which is located 52 km from Rocky Island. Circle Point is located approximately 26 km from the Taku River, where a large fall run of chum salmon also occurs.[8]

Fall Ephemeral Haulouts

Point Carolus and Little Island (Figure 9) were only occupied during fall. This period of occupancy occurs when sea lions are traveling from rookeries on the outer coast to haulouts in the inside waters.

Spatial Relationships between Sea Lion Haulouts and Forage Fish Aggregations

Hypothesis 1: Location of spring ephemeral haulouts

Spring peak haulouts were located significantly closer to forage fish aggregations than haulouts that peaked at other times of year (ANOVA, $F_{1,23} = 13.71$, $P = 0.001$) (Figure 10). Spring peak haulouts were located on average 11.8 km (SE = 2.9) from the closest forage fish aggregations. Haulouts that peaked at other times of year were located on average 29.8 km (SE = 4.7) from the closest forage fish aggregations.

[8] McGregor, A.J., and Marshall, S.L. 1982. Origins of chum salmon (*Oncorhynchus keta*) in the Excursion Inlet purse seine fishery of 1981 based on scale pattern analysis. Informational Leaflet 201. Juneau, AK. Alaska Department of Fish and Game, Division of Commercial Fisheries. 34p.

Hypothesis 2: Number of sea lions vs. distance to closest forage fish aggregation

The maximal number of sea lions at haulouts in spring was inversely associated with the distance to the closest forage fish aggregation (herring and eulachon combined) ($r = 0.57$, $n = 21$, $P = 0.005$). This relationship reflects only the inverse association of maximal number of sea lions at haulouts with distance to the closest eulachon spawning aggregation ($r = 0.80$, $n = 9$, $P = 0.01$), because there was no detectable association with herring aggregations ($r = 0.42$, $n = 12$, $P = 0.17$).

Hypothesis 3: Number of sea lions vs. number of forage fish aggregations

The maximal number of sea lions at haulouts in spring was positively associated with the number of eulachon and herring spawning sites between 20-40 km (Table 3). This relationship reflects only an association with the maximal number of sea lions at haulouts with the number of eulachon spawning sites (Table 3), because there was no consistent association with the number of herring aggregations (Table 3).

<u>Steller Sea Lions at Spring-Spawning Fish Aggregations</u>

The number of sea lions attending forage fish spawning aggregations ranged from 0 to 949 for both herring and eulachon (Figure 11a and 11b). Spring spawning aggregations of herring at Sitka Sound and Seymour Canal attracted more than 200 sea lions during the spawning period, with the greatest number of sea lions occurring in Sitka Sound (Figure 11b). For eulachon runs, the greatest number of sea lions was at Berners Bay, Taku Inlet, and Lutak Inlet with the maximal number of sea lions occurring in Berners Bay (Figure 11a).

Hypothesis 4: Number of sea lions vs. biomass/density of spawning fish

The log of the maximal number of sea lions observed at herring spawning sites was not significantly related to the biomass of herring ($r^2 = 0.45$, $n = 6$, $P = 0.14$) (Figure 12). These results should be interpreted with caution, given the small sample sizes for which herring biomass data and sea lion counts are available. Sitka Sound (50,302 tons) and Seymour Canal (10,849 tons) represent two of the largest herring spawner return sites in southeastern Alaska[2] and the number of sea lions at each of these sites was greater than at other herring spawning sites that were surveyed (Figure 11b).

The log of maximum number of sea lions that were observed at eulachon spawning sites was significantly correlated with the estimated eulachon river spawning area (km^2) (used as a index for abundance of eulachon) ($r^2 = 0.47$, $n = 9$, $P = 0.04$,) (Figure 13). In Berners Bay, where eulachon abundance was estimated by acoustic surveys, sea lion abundance increased as eulachon entered the bay, peaked as eulachon abundance peaked, and decreased as the eulachon began to move into the rivers to spawn.[9]

DISCUSSION

<u>*Sea Lions and Spring-Spawning Aggregations of Eulachon*</u>

The spatial distribution of sea lions during spring clearly reflects the seasonal availability of prey resources. Spring ephemeral haulouts were located closer to eulachon spawning sites than other haulout types. In addition, the maximal numbers of sea lions at

[9] Personal communication from Mike F. Sigler, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11130 Glacier Highway, Juneau, AK 99801, January 2003.

haulouts were closer to eulachon spawning sites. Eulachon are high in lipid content (Perez 1994; Payne *et al.* 1999; Anthony 2000; Iverson *et al.* 2002) and are densely aggregated during spring (Marston *et al.* 2002) when energetic demands are high for Steller sea lions (Winship *et al.* 2002; Winship and Trites 2003). The eulachon spawning period in southeastern Alaska may range from a few days to a few weeks with spawning runs further south usually occurring earlier than in the north. The pulsed nature of the eulachon resource makes the spawning period difficult to detect, and sea lions may stage in areas that are close to eulachon spawning sites to minimize the travel distance.

Use of haulout sites by sea lions is probably influenced by the energetic costs associated with the travel distance to foraging sites. At close distances (10-40km), the number of sea lions at haulouts was correlated with the number of eulachon spawning sites. The trip length and home range area for adult females tracked in winter were significantly greater than for adult females tracked in summer (Merrick and Loughlin 1997). In addition, two of the five adult females tagged in winter made relatively short trips, averaging 53 km, and returned to the same haulout site, suggesting that they were returning to provision dependent pups at haulout sites (Merrick and Loughlin 1997). Proximity to high-energy prey resources may also be critical for recently weaned and juvenile sea lions, which may still be developing their diving and foraging behavior. For juvenile sea lions greater than 10 months of age, the mean trip distance was 24.6 km and increased during April and May (Loughlin *et al.* 2003).

Importance of Pacific Herring

Pacific herring may be an important seasonally occurring prey species not only in spring but also in fall and throughout the winter. The energy density of herring varies seasonally (Paul *et al.* 1998) and is highest during fall (Iverson *et al.* 2002). The number of sea lions peak at Benjamin Island and Tenakee Cannery Point in spring and fall. Herring was one of the most frequent prey items in the scat of sea lions during all seasons at Benjamin Island during 2001 ($n = 252$ scat samples), and ranged from 86 to 98% (Table 4).

Benjamin Island and Tenakee Cannery Point are located close to aggregations of herring. Herring spawning grounds are usually close to herring overwintering areas (Hay and McCarter 1997, Thomas and Thorne 2001). Herring arrive at wintering areas in October and November (Carlson 1980) and may use the same wintering areas each year (Rounsefell 1930). During winter days, herring schools remain along the bottom in dense concentrations. At night, herring migrate vertically in the water column (Carlson 1980), making themselves vulnerable to predation by sea lions at shallower depths (Thomas and Thorne 2001). Beginning in March, herring move to the spawning grounds and remain in the vicinity until spawning occurs. After the spring spawning season, herring typically move to summer feeding areas located along the outer coast and around highly productive areas such as Cape Ommaney and Point Adolphus (Rounsefell 1930). Thus, the seasonal movement of sea lions from outer coast areas to inside waters, particularly to spring/fall haulout sites such as Benjamin Island and Tenakee Cannery Point, may be related to the seasonal movement of herring from summer feeding areas to more sheltered inlets and bays in winter in southeastern Alaska. Ultimately, the use of haulout sites close to over-wintering aggregations of herring allows for exploitation by sea lions when herring are found densely aggregated in predictable locations and are at their highest energy density in fall.

Pacific Salmon as a Seasonal Prey Resource

Although in some cases the distribution of sea lions at haulouts reflected the distribution of spring-spawning fish, some haulouts, especially in Frederick Sound, were occupied throughout the year although numbers of sea lions peaked during summer, particularly in July and August.

Peak numbers of sea lions at haulouts in Frederick Sound coincided with the return of pink salmon to the area. At four sites in Frederick Sound, 2,715 sea lions were counted during August 2001. At the same sites in Frederick Sound in 2002, 3,225 sea lions were counted representing 21% of the southeastern Alaska sea lion non-pup population of sea lions.[10] In contrast, no sea lions were observed at haulouts in Lynn Canal during August 2001. In 2002, only 133 sea lions were counted at Little Island in Lynn Canal. Three other sea lions haulout sites (Graves Rocks, South Marble Island, and Northwest Inian Island) in the Icy Strait/Cross Sound area were occupied by sea lions during August of 2002 and 2003.

Frederick Sound is one of the main migratory corridors for pink salmon returning to southeastern Alaska spawning grounds in July and August (Heard 1991). The majority

[10] Personal communication from Charles Stinchcomb, National Marine Fisheries Service, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92307, December 2002.

of pink salmon return to northern Southeast Alaska from the Gulf of Alaska, through the Icy Strait/Cross Sound corridor. After entering Icy Strait, pink salmon travel north through northern Chatham Strait or south down Chatham Strait and then through Frederick Sound en route to spawning grounds in Stephens Passage and Frederick Sound.[11] In contrast to Frederick Sound, Lynn Canal has a much lower density of pink salmon stocks (Halupka *et al.* 2000), which may partially explain the movement of sea lions out of Lynn Canal during summer.

The pre-spawning behavior of pink salmon makes them easy prey for Steller sea lions, because salmon aggregate in bays and estuaries from 15-35 days before reaching sexual maturity and entering fresh water to spawn (Davidson *et al.* 1943). Although the lipid content of salmon may decrease upon entry into fresh water, the final phases of oceanic migration prior to fresh water entry offer the last chance for salmon to acquire energy stores for the upstream migration (Hendry and Berg 1999). Thus salmon may offer high-energy rewards to sea lions at that time.

Large runs of salmon occur in fall in some rivers in southeastern Alaska (Halupka *et al.* 2000) and may also influence the distribution of sea lions. Late runs of chum (*Oncorhynchus keta*) and coho (*Oncorhynchus kisutch)* salmon occur in the Chilkat River in northern Lynn Canal beginning in October and November, with the chum run being the most productive in the region (Halupka *et al.* 2000). Sea lions return to haulout sites in Lynn Canal in fall just prior to the commencement of the large salmon runs on the

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[11] Hoffman, S.H. 1982. Northern southeastern Alaska pink salmon (*Oncorhynchus gorbuscha*) tagging investigations, 1877-1980. Informational Leaflet No. 106. Alaska Department of Fish and Game Division of Commercial Fisheries, Ketchikan, Alaska.

Chilkat River. The occurrence of salmon in the diet of sea lions at Benjamin Island was greatest during fall and winter (Jamie Womble, *unpublished data*) and it is probable that sea lions at Benjamin Island may intercept salmon en route to their fall spawning grounds in northern Lynn Canal. Salmon occur seasonally in the diet of Steller sea lions throughout much of the range (Pitcher 1981; Merrick *et al.* 1997; Sinclair and Zeppelin 2002; Winship and Trites 2003) and ultimately may be another important high-energy prey resource that influences the seasonal distribution of sea lions.

Seasonal Changes in Distribution of Prey Species and Sea Lions

While seasonal changes in the distribution and abundance of sea lions have been documented (Bonnot 1951; Bartholomew and Boolootian 1960; Kenyon and Rice 1961; Mathisen and Lopp 1963; Mate 1975; Harestad 1977; Calkins and Pitcher 1982;[1] Sullivan 1980; Bigg 1988), previous survey efforts focused on the breeding season (May-Aug). Documenting abundance of Steller sea lions during the breeding season is important; however, elucidating seasonal shifts in abundance and distribution is important as it relates to life-history characteristics of sea lions and their prey species. The energy density of prey species changes seasonally, so some fish species may be more valuable to exploit than others at particular times of year (Jangaard 1974; Montevecchi and Piatt 1984; Mårtensson *et al.* 1996; Iverson *et al.* 2002). Efforts focused only during the breeding season would not reflect seasonally available prey species that may influence the distribution, diet, and ultimately the energetics of sea lions. For example, eulachon are not a commonly occurring prey species in the diet of sea lions during the breeding season (Merrick *et al.* 1997; Sinclair and Zeppelin 2002), and dietary studies focused only during the breeding season would not reflect the importance of particular prey items. Furthermore, when Steller sea lions aggregate at the eulachon and herring spawning sites in spring they do not return to haulout sites regularly, but often raft up and rest near the foraging site, so even scat collection at haulouts during the spring may not detect the presence of these seasonally pulsed prey in the diet.

Implications for Steller Sea Lion Energetics

The energetic requirements of otariids vary seasonally and with reproductive state (Costa and Gales 2003). Lactation is a very costly part of mammalian reproduction (Gittleman and Thompson 1988). In northern fur seals (*Callorhinus ursinus*), the estimated average daily feeding rate for lactating females was 1.6 times greater than for non-lactating females (Perez and Mooney 1986). For Steller sea lion non-pups, bioenergetic models indicate that daily food requirements were highest during winter and spring and were lower during summer (Winship *et al.* 2002). The period of pup dependency for Steller sea lions is usually one year but in some cases may be even longer (Gentry 1970; Sandegreen 1970). Thus, much of the adult female energy expenditure is at a terrestrial site where she is unable to feed (Oftedal *et al.* 1987), requiring the female to make intermittent trips to meet her and her pup's energy requirements. A female nursing a pup during spring may need to consume two times the energy that a female without a pup would require (Winship *et al.* 2002). In order to meet the energetic demands of the costly otariid reproductive strategy, locating haulouts close to high-energy prey resources is advantageous during spring, an energetically demanding time for sea lions (Winship *et al.* 2002; Winship and Trites 2003)

Upon arrival at the rookery, males attempt to establish territories, which they may remain on for 20-68 days without feeding (Thorsteinson and Lensink 1962; Gentry 1970; Sandegreen 1970; Gisiner 1985). In male gray seals (*Halichoerus grypus*), energy is accumulated during the pre-breeding foraging period, which is then expended during the breeding and post-breeding period (Beck et al. 2003). Thus, foraging at spring-spawning aggregations of herring and eulachon should allow Steller sea lion males to arrive at rookeries in good condition. Larger more fit males are likely to successfully defend territories for longer periods of time (Boyd and Duck 1991) and mate with more females thus increasing their reproductive success (Bartholomew 1970).

Energy demands for both male and female Steller sea lions are high in spring when herring and eulachon are densely aggregated. Seasonally aggregated, high-energy prey species influence the seasonal distribution of sea lions in southeastern Alaska, and the location of haulout sites near seasonally predictable prey concentrations is probably an adaptation to the costly reproductive strategy of otariids.

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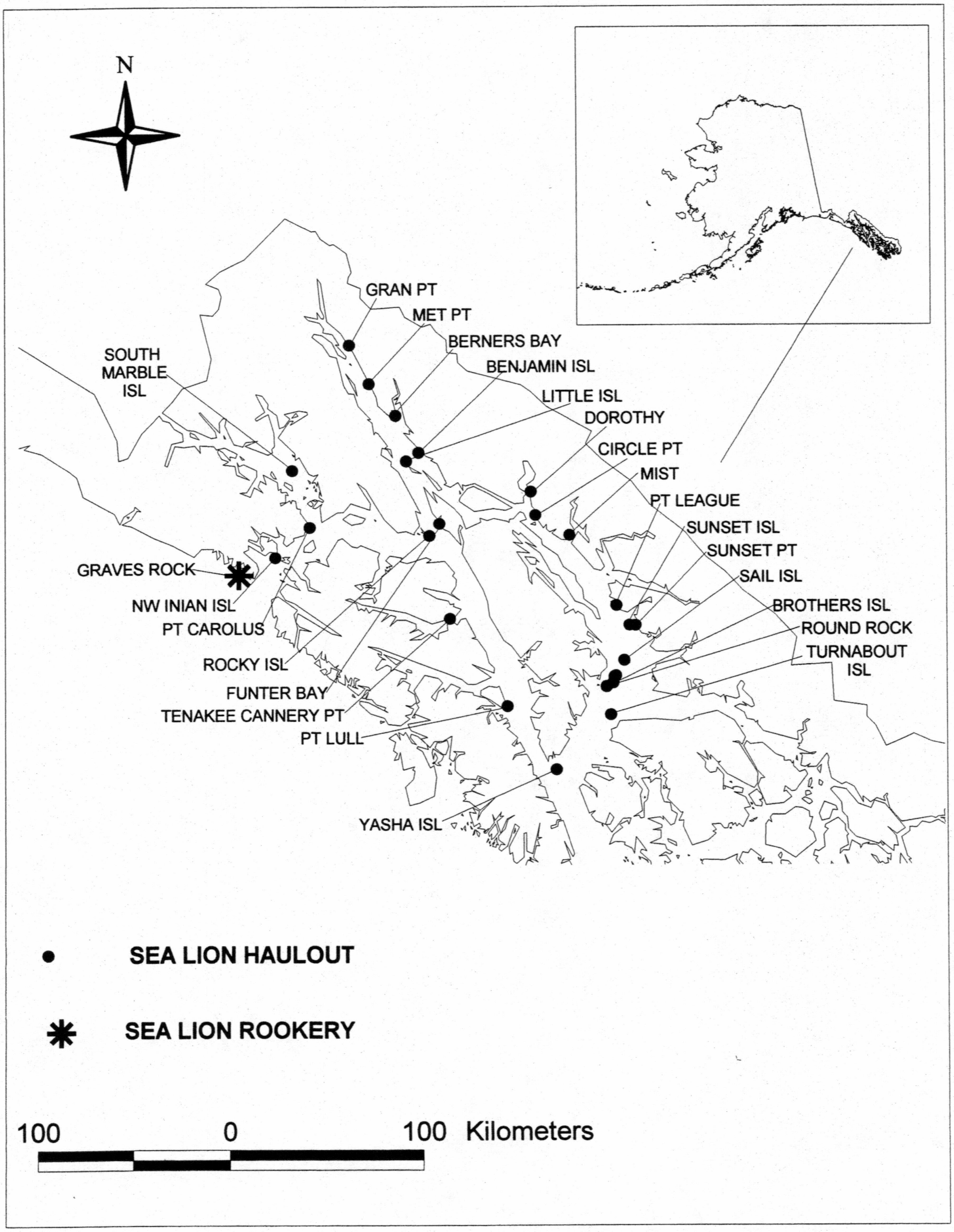


Figure 1. Study area where monthly aerial surveys were conducted at Steller sea lion haulouts and rookeries in southeastern Alaska.

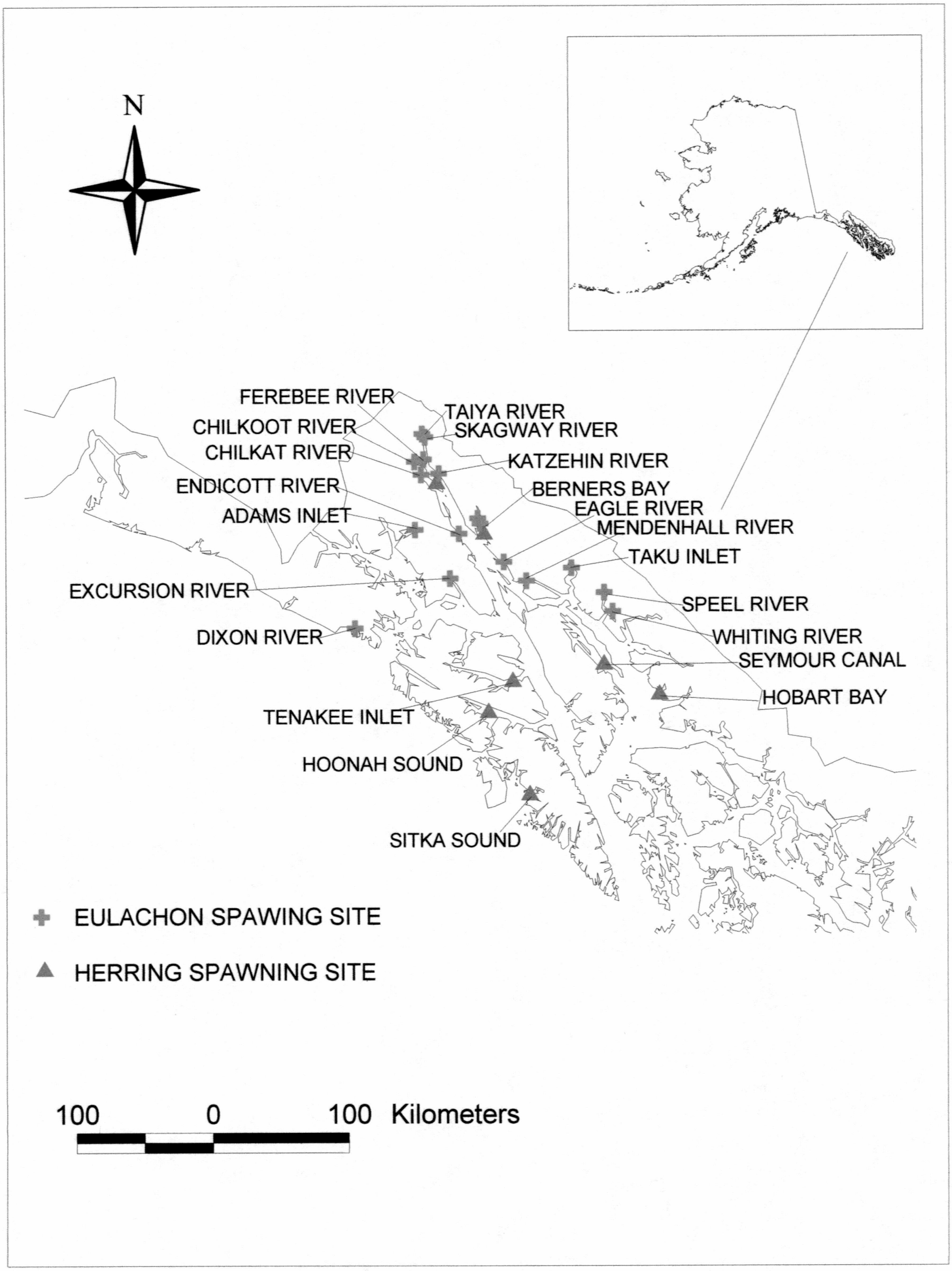


Figure 2. Location of aerial surveys at herring and eulachon spawning sites during spring of 2002.

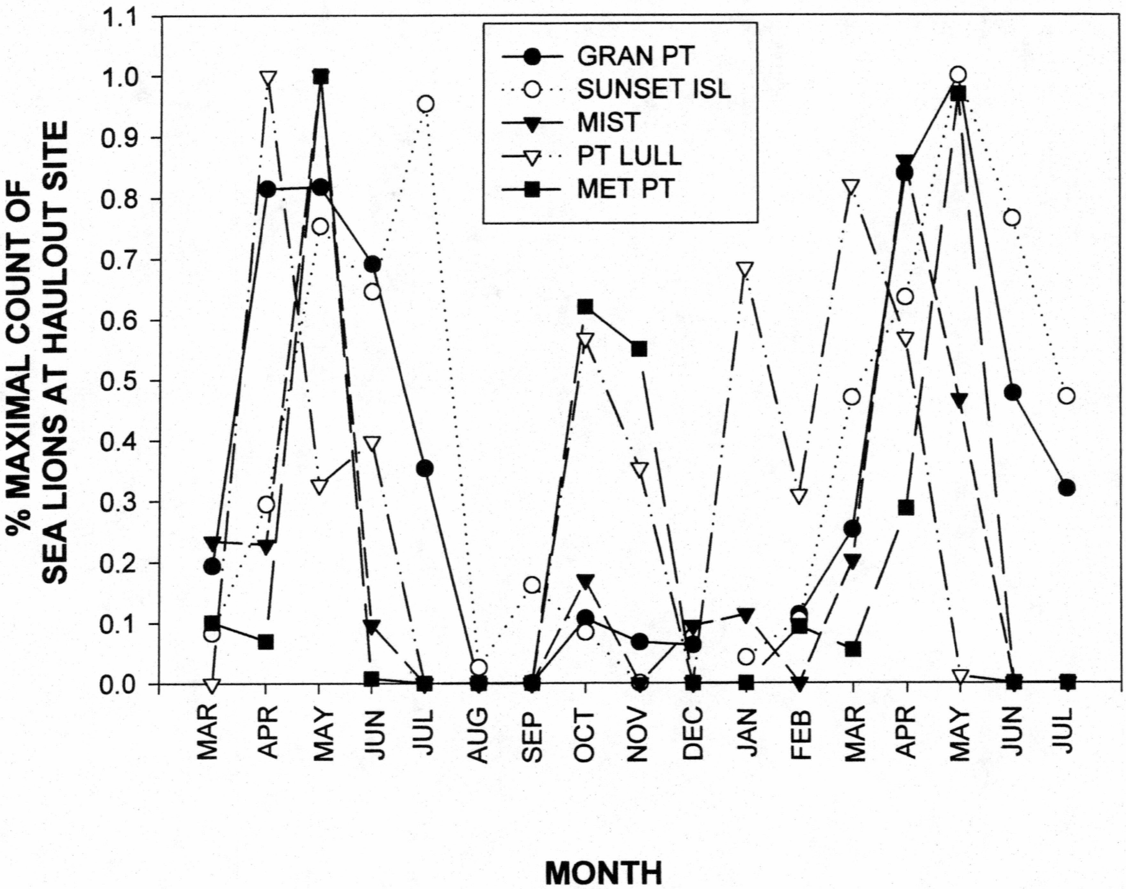


Figure 3. Percentage of maximal count of sea lions at spring peak haulout sites during monthly aerial surveys from March 2001 to July 2002.

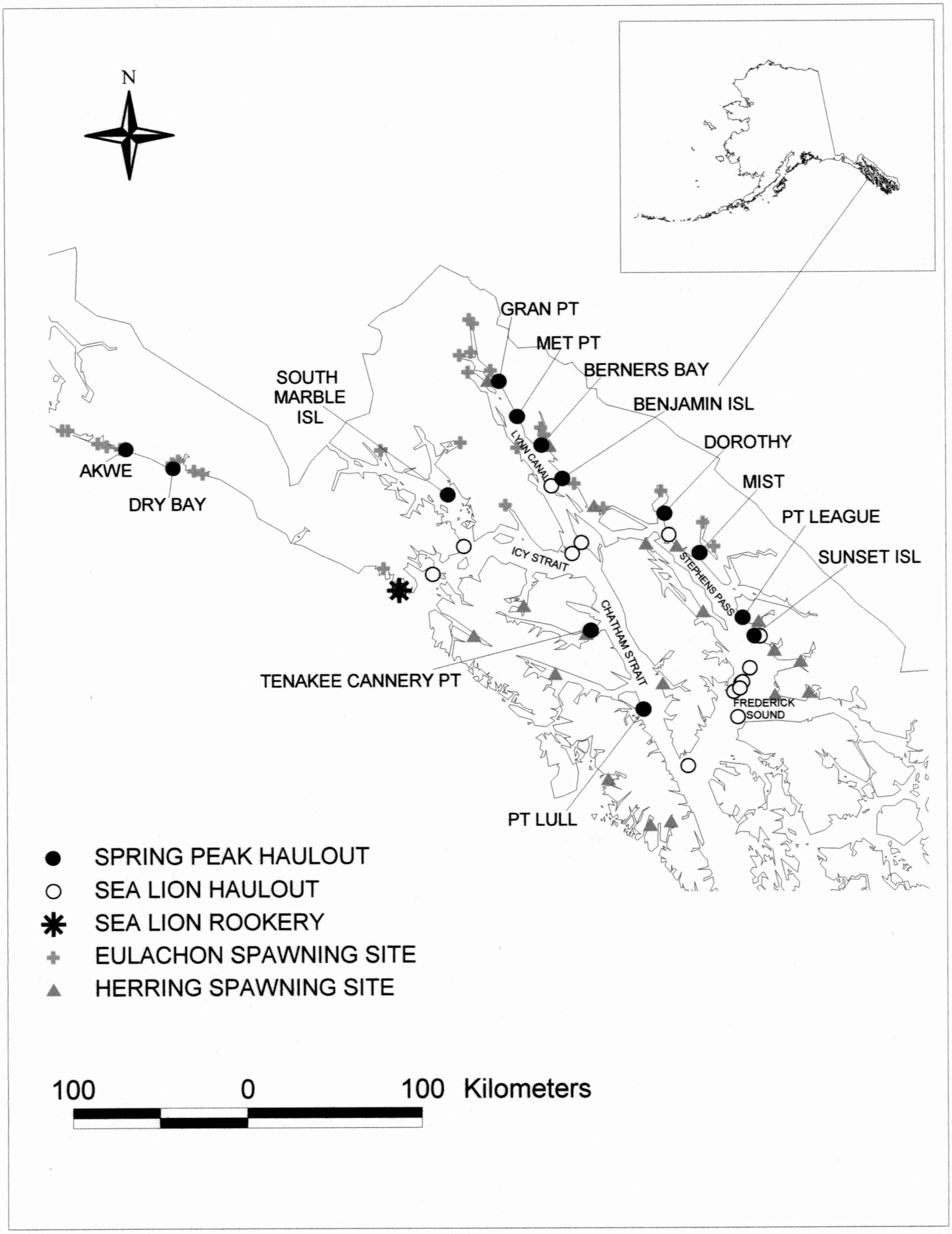


Figure 4. Location of Steller sea lion haulouts where numbers of sea lions ashore peaked in spring. Also shown above are eulachon and herring spawning sites.

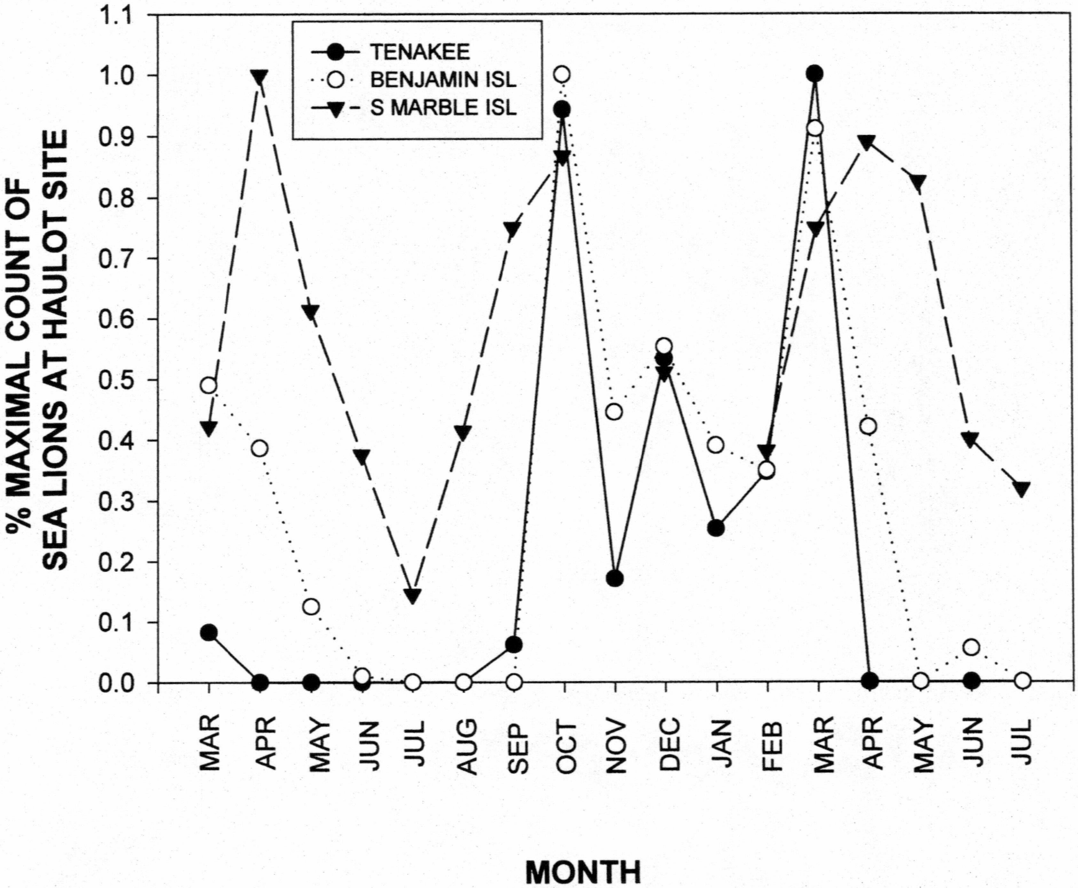


Figure 5. Percentage of maximal count of sea lions at spring/fall peak haulout sites during monthly aerial surveys form March 2001 to July 2002.

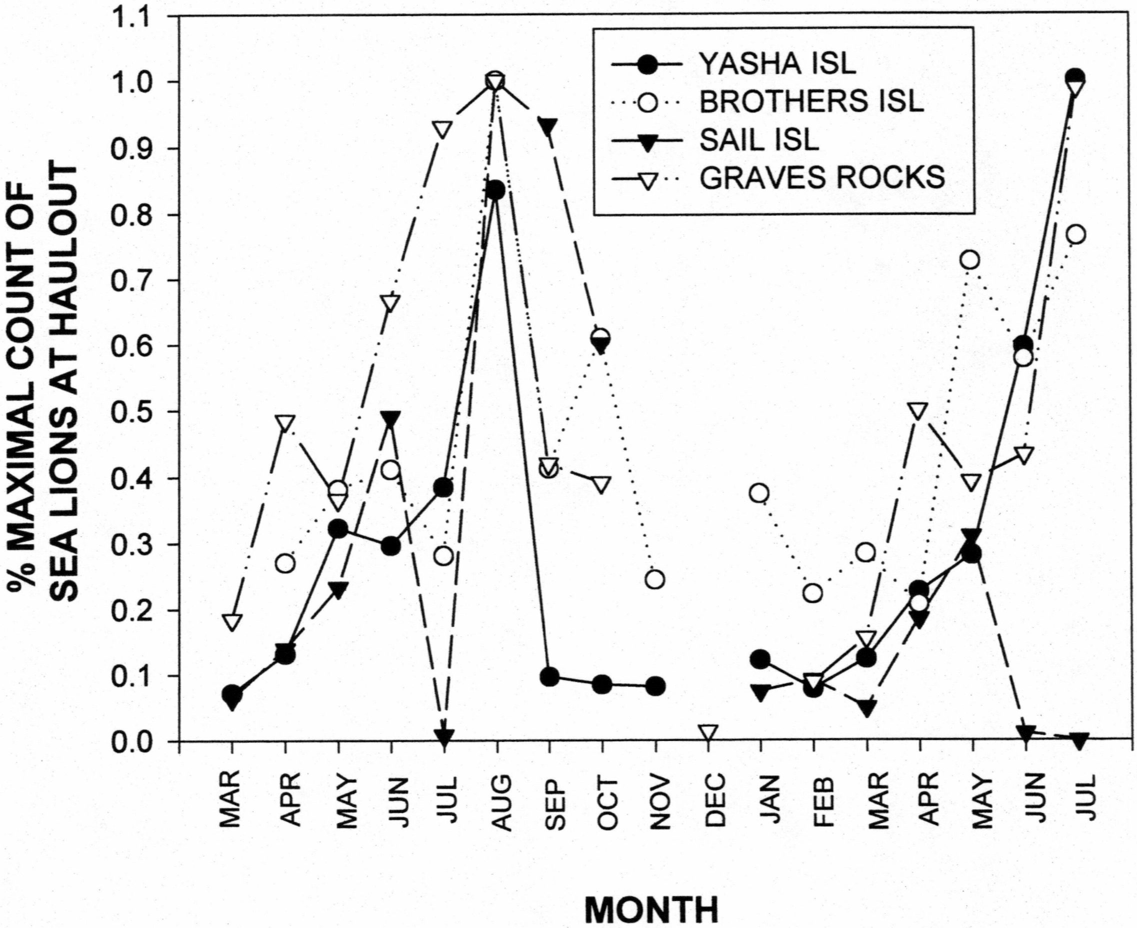


Figure 6. Percentage of maximal count of sea lions at summer peak haulout sites during monthly aerial surveys from March 2001 to July 2002.

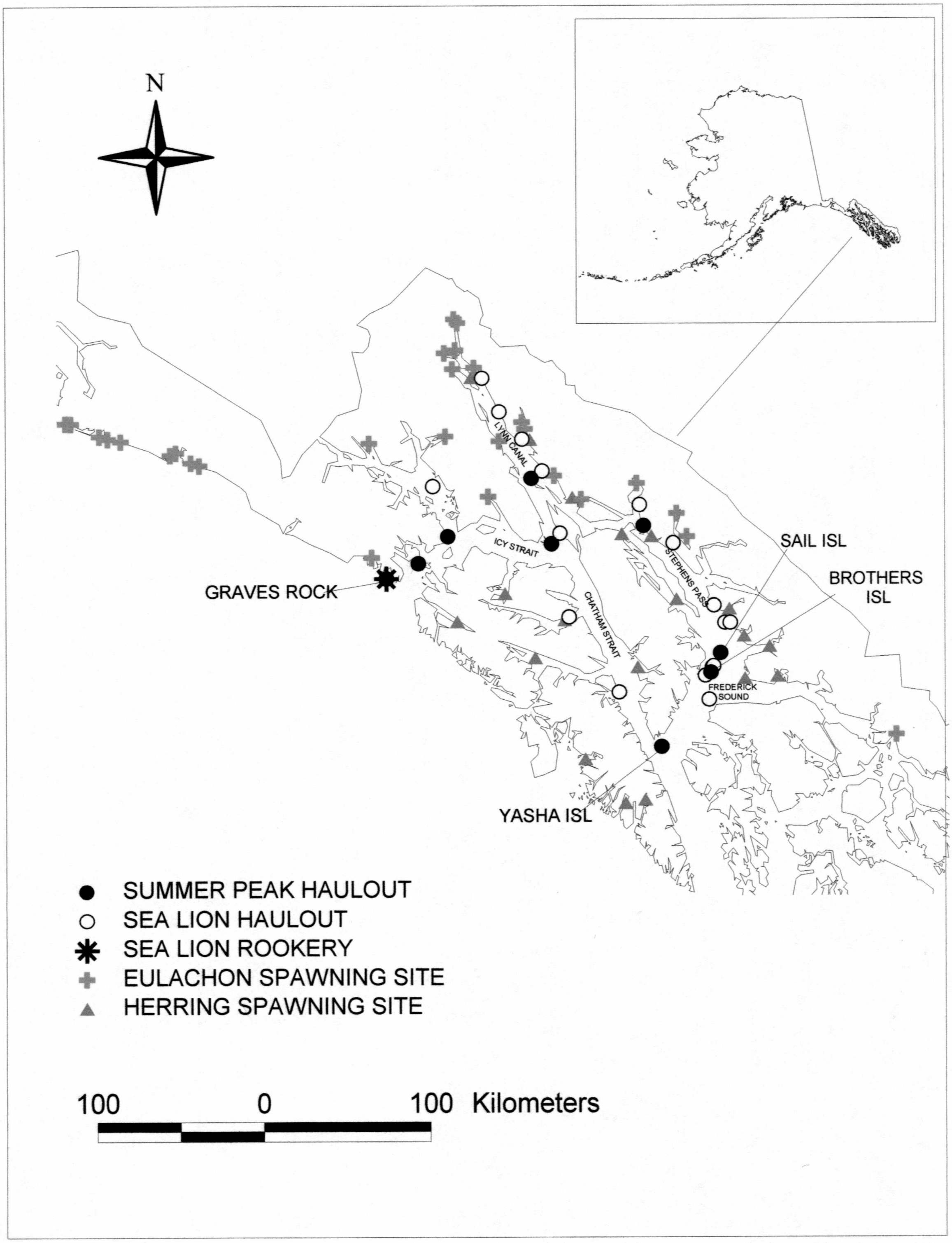


Figure 7. Locations of Steller sea lion haulouts where numbers of sea lions ashore peaked in summer. Also shown are eulachon and herring spawning sites.

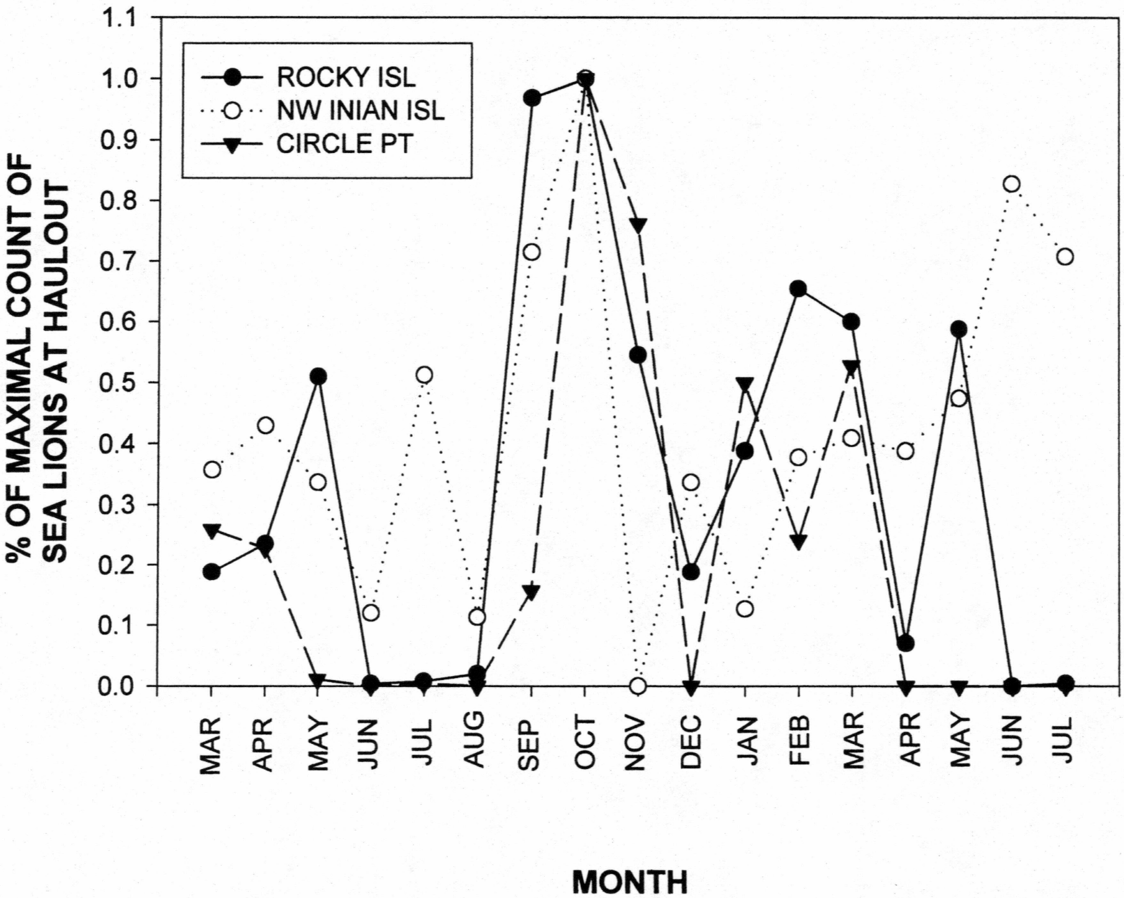


Figure 8. Percentage of maximal count of sea lions at fall peak haulout sites during monthly aerial surveys from March 2001 to July 2002.

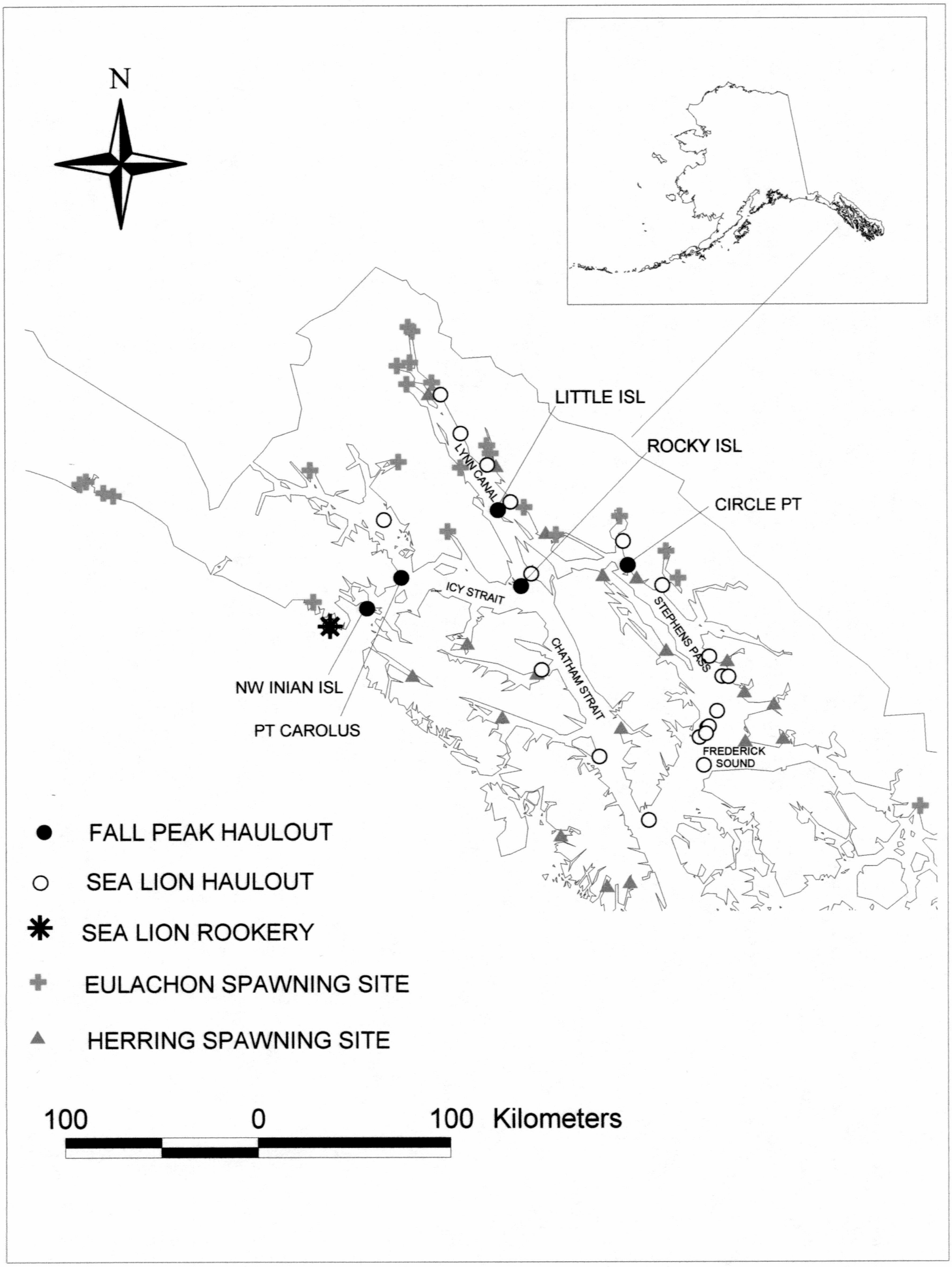


Figure 9. Locations of Steller sea lion hualouts where numbers of sea lions ashore peaked in fall. Also shown are eulachon and herring spawning sites.

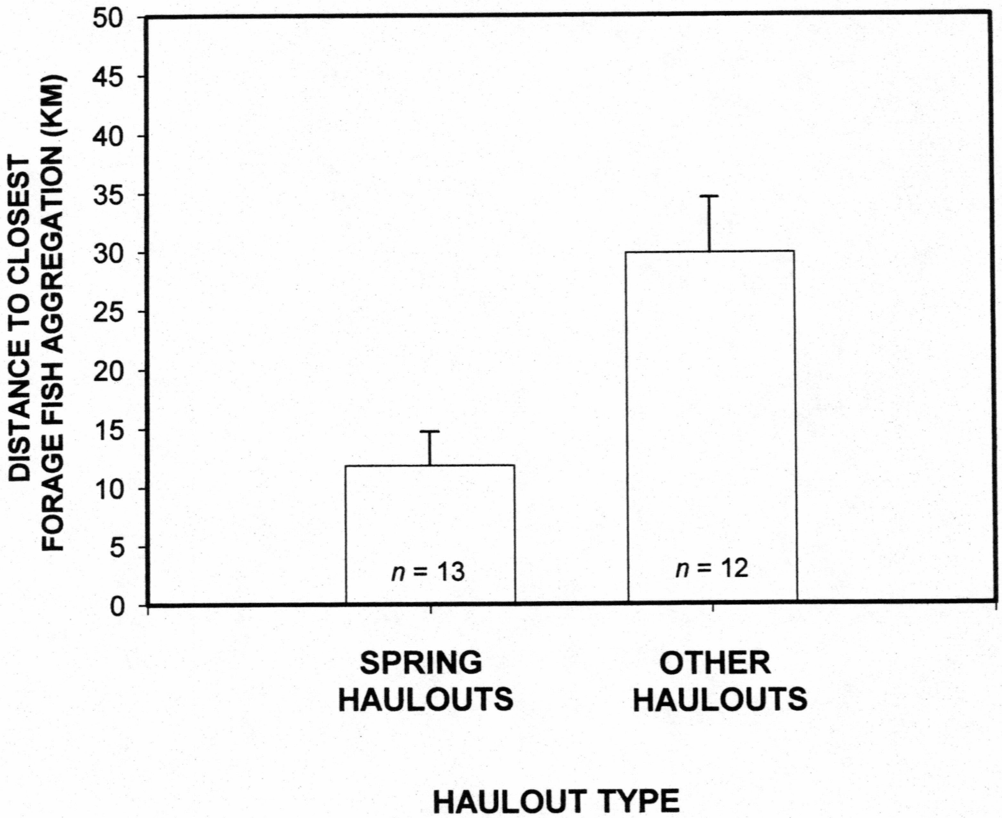
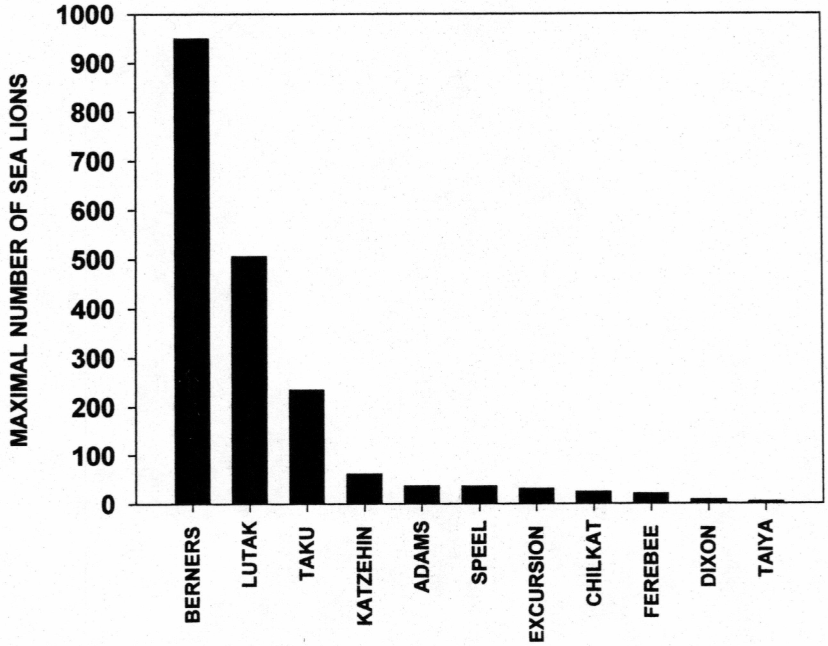


Figure 10. Average distance to closest forage fish aggregation (km) for Steller sea lion haulouts that peak in numbers in spring and for haulouts that peak at other times of year. Significant difference by ANOVA: $F_{1,23} = 13.71$, $P = 0.001$.

a) Eulachon Spawning Sites



b) Pacific Herring Spawning Sites

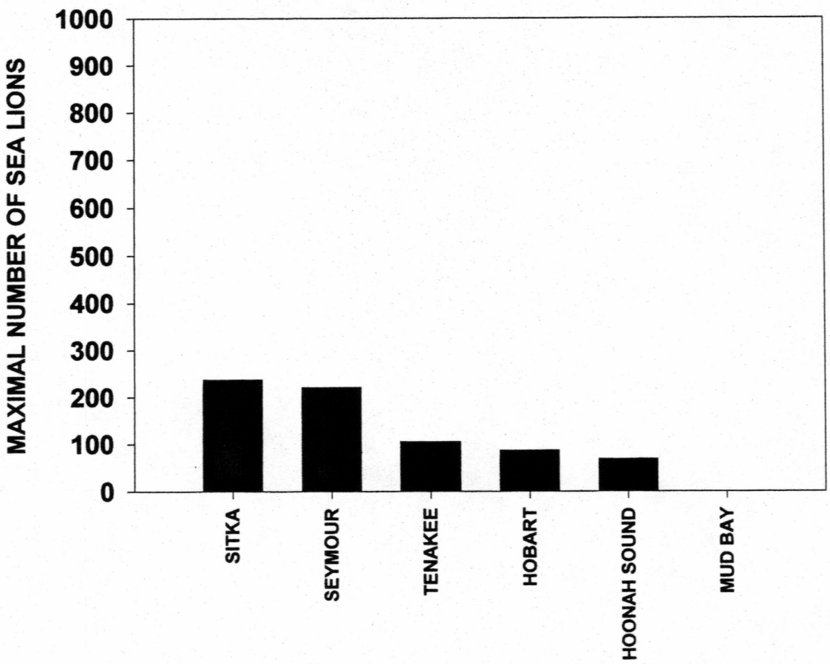


Figure 11. Maximal number of sea lions observed in the water at spring-spawning aggregations of eulachon and Pacific herring during 2002 aerial surveys in southeastern Alaska.

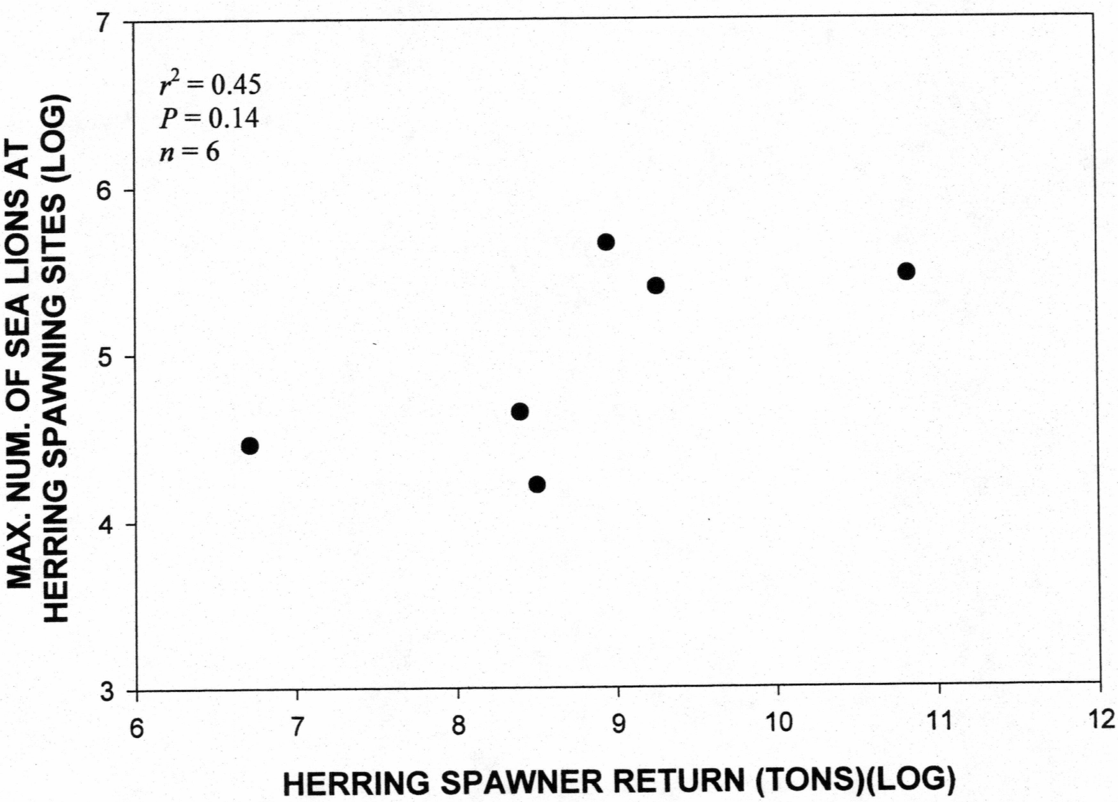


Figure 12. Maximal numbers of sea lions (log) observed at herring spawning sites in relation to the estimated herring spawner return. Estimates of herring spawner return obtained from Dave Carlile-Division of Commerical Fisheries, Alaska Department of Fish and Game, Douglas, Alaska.

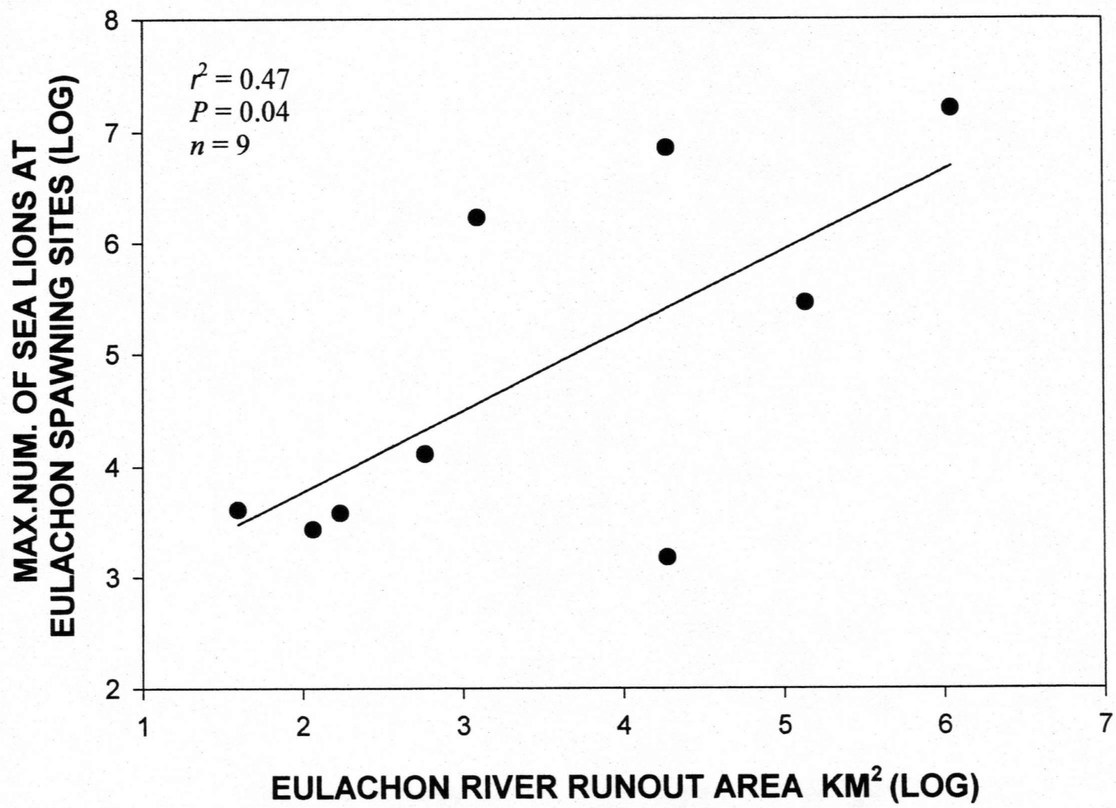


Figure 13. Maximal numbers of sea lions (log) observed at eulachon spawning sites during spring 2002 in relation to index of eulachon.

Table 1. Pinnipeds at forage fish aggregations in the Northeastern Pacific Ocean.

LOCATION	FORAGE FISH SPECIES	PINNIPED SPECIES	SOURCE
Berners Bay, AK	E	HS, SSL	Marston et al. 2002, Gende et al. 2001, this study
Dry Bay/Alsek River, AK	E	SSL	William G. Lucey, *pers. comm.*[a]
Stikine River, AK	E	HS	William Bergman, *pers. comm.*[b]
Copper River, AK	E	HS	Imler and Sarber 1947
Adams Inlet	E	HS, SSL	this study
Taku River, AK	E	HS, SSL	this study
Chilkat River, AK	E	HS, SSL	this study
Chilkoot River, AK	E	HS, SSL	this study
Endicott River, AK	E	HS	this study
Excursion River, AK	E	SSL	this study
Ferebee River, AK	E	HS, SSL	this study
Katzehin River, AK	E	SSL	this study
Speel River, AK	E	HS, SSL	this study
Whiting River, AK	E	HS	this study
Dixon River, AK	E	HS, SSL	this study
Taiya River, AK	E	HS,SSL	this study
Columbia River, WA	E	HS	Jefferies et al. 1986[c]
Fraser River, BC	E	HS, SSL	Bigg 1988
Lower Kitimat River, BC	E	HS	Pedersen et al. 1995[d]
Bristol Bay, AK	H	HS, SSL	John J. Burns, *pers. comm.*[e]
Seymour Canal, AK	H	SSL	this study
Craig, AK	H	SSL	this study
Sitka Sound, AK	H	SSL	this study
Hoonah Sound, AK	H	SSL	this study
Tenakee Inlet, AK	H	SSL	this study
Annette Island, AK	H	SSL	this study
West Behm Canal, AK	H	SSL	this study
Prince William Sound, AK	H	SSL	Brown et al. 1999, Thomas and Thorne 2001
Hobart Bay, AK	H	SSL	Kruse et al. 2000,[f] this study
Togiak, AK	H	SSL	Tim Sands, *pers. comm.*[g]
Kamishak Bay, AK	H	HS, SSL	Ted Otis, *pers. comm.*[h]
Cordova Harbor, AK	H	SSL	Brian Marston, *pers. comm.*[i]
San Juan Islands, WA	H, SL	HS	Zamon 2001
Lituya Bay, AK	C	SSL	Acuna et al. 1983[j]
Monterey Bay, CA	A	HS, CSL	Brendan P. Kelly, *pers. comm.*[k]

PINNIPED SPECIES

CSL = California Sea Lion (*Zalophus californianus*)

HS = Harbor Seal (*Phoca vitulina*)

SSL = Steller Sea Lion (*Eumetopias jubatus*)

FISH SPECIES

A = Anchovy (*Engraulis mordax mordax*)

C = Capelin (*Mallotus villosus*)

E = Eulachon (*Thaleichyths pacificus*)

H = Pacific Herring (*Clupea pallasii*)

SL = Pacific Sandlance (*Ammodytes hexapterus*)

Table 1. (cont'd).

Sources of Personal Communication and Unpublished Reports

[a] William G. Lucey, Fisheries Biologist, U.S.D.A. Forest Service, Yakutat Ranger District, P.O. Box 327, Yakutat, Alaska 99869.

[b] William Bergmann, Fisheries Biologist, Alaska Department of Fish and Game, Commercial Fisheries Division, P.O. Box 667, Petersburg, Alaska 99833.

[c] Jeffries, S.J. 1986. Seasonal movements and population trends of harbor seals (*Phoca vitulina richardsi*) in the Columbia River and adjacent waters of Washington and Oregon: 1976-1982. Washington Department of Game, Wildlife Management Division, 600 North Capitol Way, Olympia, Washington 98504.

[d] Pedersen, R.V.K. , Orr, U.N., and Hay, D.E. 1995. Distribution and preliminary stock assessment (1993) of the Eulachon, *Thaleichthys pacificus*, in the Lower Kitimat River, British Columbia.Canadian Manuscript Report of Fisheries and Aquatic Sciences 2330: 20 p.

[e] John J. Burns, Living Resources, P.O. Box 83570, Fairbanks, Alaska 99708

[f] Kruse, G.H., Funk, F.C., Geiger, H.J., Mabry, K.R., Savikko, H.M., and Siddeek, S.M. 2000. Overview of state-managed marine fisheries in the central and western Gulf of Alaska, Aleutian Islands, and southeastern Bering Sea, with reference to Steller sea lions. Regional Information Report 5J00-10. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska.

[g] Tim Sands, Fisheries Biologist, Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box230, Dillingham, Alaska 99576.

[h] Ted Otis, Fisheries Biologist, Alaska Department of Fish and Game, Division of Commercial Fisheries, 3298 Douglas Place, Homer, Alaska 99603.

[I] Brian Marston, Fisheries Biologist, Alaska Department of Fish and Game, P.O. Box 669, Cordova, Alaska 99574.

[j] Acuna, C.A., and Selig, L.F. 1983. Population observations at Lituya Bay. Unpublished report. Glacier Bay National Park and Preserve, Gustavus, Alaska.

[k] Brendan P. Kelly, University of Alaska, 11120 Glacier Highway, Juneau, Alaska 99801.

Table 2. Mean and standard error (SE) of lipid percent dry mass and energy density (kJ g^{-1} dry mass) of adult Pacific herring and eulachon.

SPECIES	SITE	LIPID % dry mass (SE)	ENERGY DENSITY (kJ g-1 dry mass)(SE)	N	SEASON	SOURCE
Herring	PWS	4.7 (0.32)	-	39	Spring	Iverson et al. 2002
	PWS	8.0 (0.86)	-	21	Summer	Iverson et al. 2002
	PWS	14.2 (0.44)	-	37	Fall	Iverson et al. 2002
	GOA	26.8 (.70)	21.3 (0.19)	34	May-Aug	Anthony et al. 2000
	PWS	-	23.86 (1.19)	49	April	Paul and Paul 1999
	BS/GOA	-	26.00	20	Summer	Perez 1994
Eulachon	PWS	19.0 (0.52)	-	20	Spring	Iverson et al. 2002
	GOA	50.0 (0.80)	27.2 (0.19)	34	May-Aug	Anthony et al. 2000
	GOA	18.82 (0.25)	-	120	Feb.-Sept.	Payne et al. 1999
	BS	19.87 (0.22)	-	17	June-Sept.	Payne et al. 1999
	BS	-	30.77	29	Summer	Perez 1994

LOCATION

GOA=Gulf of Alaska

PWS = Prince William Sound

BS = Bering Sea

Table 3. Spearman rank correlation coefficients between number of forage fish aggregations at designated distances and the maximum number of sea lions at haulouts during spring 2002.

	ALL FFA		HERRING		EULACHON	
Distance (km)	r_s	p	r_s	p	r_s	p
5	0.36	0.10	0.15	ns	0.37	0.10
10	0.34	0.10	-0.06	ns	0.55	0.01
20	0.54	0.01	0.17	ns	0.55	0.01
25	0.36	0.10	-0.15	ns	0.57	0.005
30	0.40	0.05	-0.05	ns	0.56	0.005
40	0.42	0.05	-0.07	ns	0.56	0.005
50	0.18	ns	-0.26	ns	0.31	0.1
65	0.08	ns	-0.32	0.10	0.23	ns
100	0.20	ns	-0.32	0.10	0.22	ns
135	-0.09	ns	-0.29	ns	0.15	ns
150	-0.18	ns	-0.52	0.01	0.24	ns
195	-0.10	ns	0.24	ns	0.07	ns

ALL FFA = All forage fish aggregations (herring and eulachon combined)
ns = not significant

Table 4. Frequency of occurrence (FO) of Pacific herring in Steller sea lion scat collected at Benjamin Island during 2001.

MONTH	FO OF HERRING IN SEA LION SCAT	*n*
February	92.0%	50
April	95.7%	47
October	86.7%	98
December	98.2%	57

APPENDIX

Table A-1. Latitude and longitude (decimal degrees) coordinates of Steller sea lion haulouts and rookery in southeastern Alaska that were surveyed monthly.

LOCATION	TYPE	LATITUDE	LONGITUDE
Benjamin Island	H	58.561667 N	134.913333 W
Circle Point	H	58.125000 N	134.08000 W
Dorothy	H	58.236667 N	134.056667 W
Funter Bay	H	58.216944 N	134.918330 W
Gran Point	H	59.133333 N	135.240000 W
Graves Rocks	R	58.238333 N	136.756667 W
Little Island	H	58.541420 N	135.041580 W
Met Point	H	58.933333 N	135.166667 W
Mist	H	57.988333 N	133.845000 W
Northwest Inian Island	H	58.271667 N	136.400000 W
Point Carolus	H	58.366667 N	136.033333 W
Point League	H	57.609167 N	133.651333 W
Point Lull	H	57.310000 N	134.806667 W
Rocky Island	H	58.175973 N	135.034318 W
Round Rock	H	57.260000 N	133.935000 W
Sail Island	H	57.351667 N	133.721667 W
South Marble Island	H	58.645000 N	136.046667 W
Southwest Brothers Island	H	57.267755 N	133.871552 W
Sunset Island	H	57.500000 N	133.586667 W
Sunset Point	H	57.490700 N	133.537700 W
Tenakee Cannery Point	H	57.775000 N	135.071667 W
Turnabout Island	H	57.130000 N	133.971667 W
Yasha Island	H	56.963333 N	134.558333 W

H = Haulout

R = Rookery

Table A-2. Latitude and longitude (decimal degrees) of eulachon and Pacific herring spawning sites in southeastern Alaska that were surveyed during spring 2002.

LOCATION	FISH SPECIES	LATITUDE	LONGITUDE
Adams Inlet	Eulachon	58.88718 N	135.776622 W
Berners Bay	Eulachon	58.8076 N	134.9586 W
Chilkat River	Eulachon	59.2265 N	135.508 W
Lutak Inlet	Eulachon	59.3205 N	135.5437 W
Dixon River	Eulachon	58.3682 N	136.8432 W
Eagle River	Eulachon	58.5218 N	134.809 W
Endicott River	Eulachon	58.7826 N	135.2513 W
Excursion River	Eulachon	58.5146 N	135.5208 W
Ferebee River	Eulachon	59.3191 N	135.4243 W
Katzehin River	Eulachon	59.2013 N	135.2856 W
Skagway River	Eulachon	59.4563 N	135.3235 W
Speel River	Eulachon	58.1352 N	133.7199 W
Taiya River	Eulachon	59.481 N	135.3479 W
Taku River	Eulachon	58.353888 N	134.017433 W
Whiting River	Eulachon	58.0002 N	133.6896 W
Mendenhall River	Eulachon	58.3583 N	134.6073 W
Seymour Canal	Herring	57.699824 N	133.979284 W
Hobart Bay/Port Houghton	Herring	57.30674 N	133.234783 W
Tenakee Inlet	Herring	57.767192 N	135.12095 W
Sitka Sound	Herring	57.016237 N	135.313823 W
Hoonah Sound	Herring	57.61533 N	135.514976 W
Flat (Mud) Bay	Herring	59.154417 N	135.344007 W

Table A-3. Number of forage fish aggregations within designated distances of sea lion haulouts.

SPECIES (DISTANCE KM)

	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T	E	H	T
LOCATION	5	5	5	10	10	10	20	20	20	30	30	30	40	40	40	50	50	50	65	65	65	100	100	100	135	135	135	150	150	150	195	195	195
BENJAMIN ISL	0	0	0	1	0	1	1	1	2	3	3	6	5	3	8	5	3	8	5	4	9	10	8	18	15	8	23	15	9	24	15	13	28
LITTLE ISL	0	0	0	0	0	0	1	0	1	3	2	5	5	3	8	5	3	8	5	4	9	11	8	19	15	9	24	15	9	24	18	14	32
MET PT	0	0	0	0	0	0	1	0	1	2	1	3	2	2	4	7	2	9	10	3	13	11	4	15	12	7	19	13	8	21	15	9	24
GRAN PT	0	1	1	1	1	2	1	1	2	4	1	5	5	1	6	7	1	8	9	2	11	10	4	14	11	5	16	11	6	17	15	8	23
S. MARBLE ISL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	0	2	3	1	4	5	4	9	6	5	11	9	9	18
PT CAROLUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	5	3	8	9	6	15	9	8	17	16	11	27
NW INIAN ISL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2	2	2	4	3	4	7	4	6	10	11	10	21
GRAVES RKS	0	0	0	0	0	0	1	0	1	1	0	1	1	0	1	1	1	2	1	1	2	1	1	2	5	2	7	7	2	9	14	9	23
ROCKY ISL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	4	7	6	7	13	12	10	22	17	11	28	17	12	29
FUNTER BAY	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	2	3	3	4	7	6	8	14	12	10	22	18	11	29	18	12	30
TENAKEE	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	2	2	0	4	4	6	7	13	6	8	14	12	13	25
PT LULL	0	0	0	0	0	0	0	1	1	0	1	1	0	1	1	0	1	1	0	3	3	0	3	3	0	6	6	1	9	10	7	13	20
YASHA ISL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	4	4	0	7	7	1	8	9	5	13	18
TURNABOUT ISL	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	3	3	0	3	3	0	5	5	3	6	9	3	9	12	6	11	17
ROUND ROCK	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2	0	3	3	0	4	4	1	6	7	3	7	10	5	9	14	6	11	17
BROTHERS ISL	0	0	0	0	0	0	0	1	1	0	2	2	0	2	2	0	3	3	0	4	4	1	5	6	3	7	10	5	7	12	6	11	17
SAIL ISL	0	0	0	0	0	0	0	1	1	0	2	2	0	2	2	0	4	4	0	4	4	2	5	7	7	7	14	7	8	15	7	12	19
SUNSET PT	0	0	0	0	0	0	0	1	1	0	1	1	0	3	3	0	3	3	0	4	4	2	6	8	4	8	12	6	9	15	9	12	21
SUNSET ISL	0	0	0	0	0	0	0	1	1	0	1	1	0	3	3	0	3	3	0	4	4	2	6	8	4	8	12	6	9	15	9	12	21
PT LEAGUE	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2	0	3	3	2	4	6	3	6	9	5	8	13	5	9	14	9	11	20
MIST	0	0	0	1	0	1	2	1	3	2	1	3	2	1	3	2	2	4	3	2	5	4	7	11	6	9	15	8	9	17	11	13	24
CIRCLE PT	0	0	0	0	1	1	0	2	2	0	2	2	0	2	2	4	3	7	4	4	8	5	7	12	9	9	18	9	12	21	15	13	28
DOROTHY	0	0	0	0	0	0	1	0	1	1	2	3	2	2	4	3	4	7	4	4	8	5	5	10	8	9	17	9	11	20	15	13	28
DRY BAY	2	0	2	3	0	3	4	0	4	4	0	4	6	0	6	7	0	7	7	0	7	9	0	9	9	1	10	10	1	11	10	2	12
AKWE	1	0	1	2	0	2	3	0	3	3	0	3	7	0	7	9	0	9	9	0	9	9	1	10	9	1	10	9	1	10	10	1	11
TOTAL	3	2	5	7	3	10	14	10	24	20	20	40	31	28	59	50	44	94	64	64	128	98	108	206	160	157	317	190	185	375	270	255	525

E = EULACHON

H = HERRING

T= EULACHON AND HERRING COMBINED

Table A-4. Distance to closest forage fish aggregation for each Steller sea lion haulout.

HAULOUT	DISTANCE TO CLOSEST FORAGE FISH AGGREGATION (KM)	FIH SPECIES
BENJAMIN ISLAND	6	EULACHON
LITTLE ISLAND	13	HERRING
MET POINT	16	EULACHON
GRAN POINT	5	HERRING
SOUTH MARBLE ISLAND	39	EULACHON
POINT CAROLUS	54	EULACHON
NORTHWEST INIAN ISLAND	43	EULACHON
GRAVES ROCKS	14	EULACHON
ROCKY ISLAND	45	EULACHON
FUNTER BAY	41	EULACHON
TENAKEE CANNERY POINT	3	HERRING
POINT LULL	16	HERRING
YASHA ISLAND	53	HERRING
TURNABOUT ISLAND	24	HERRING
ROUND ROCK	24	HERRING
BROTHERS ISLAND	17	HERRING
SAIL ISLAND	15	HERRING
SUNSET POINT	11	HERRING
SUNSET ISLAND	12	HERRING
POINT LEAGUE	23	HERRING
MIST	10	EULACHON
CIRCLE POINT	28	EULACHON
DOROTHY	14	EULACHON
DRY BAY	3	EULACHON
AKWE	3	EULACHON

Table A-5. Number of sea lions in water at eulachon and herring spawing sites during spring 2002.

DATE	LOCATION	NUMBER OF SEA LIONS
4/8/2002	ADAMS INLET	13
4/18/2002	ADAMS INLET	37
4/29/2002	ADAMS INLET	19
5/15/2002	ADAMS INLET	0
4/8/2002	BERNERS BAY	72
4/18/2002	BERNERS BAY	949
4/29/2002	BERNERS BAY	45
5/3/2002	BERNERS BAY	16
5/15/2002	BERNERS BAY	1
4/8/2002	CHILKAT INLET	0
4/18/2002	CHILKAT INLET	0
4/29/2002	CHILKAT INLET	24
5/15/2002	CHILKAT INLET	0
4/8/2002	DIXON RIVER	8
4/18/2002	DIXON RIVER	0
4/29/2002	DIXON RIVER	0
4/8/2002	EAGLE RIVER	0
4/29/2002	EAGLE RIVER	0
5/15/2002	EAGLE RIVER	0
4/9/2002	HOONAH SOUND	26
4/23/2002	HOONAH SOUND	68
5/3/2002	HOONAH SOUND	13
5/14/2002	HOONAH SOUND	0
4/8/2002	ENDICOTT RIVER	0
4/18/2002	ENDICOTT RIVER	0
4/29/2002	ENDICOTT RIVER	1
5/15/2002	ENDICOTT RIVER	0
4/9/2002	EXCURSION INLET	31
4/18/2002	EXCURSION INLET	12
4/29/2002	EXCURSION INLET	2
4/8/2002	FEREBEE RIVER	3
4/18/2002	FEREBEE RIVER	20
4/29/2002	FEREBEE RIVER	1
5/15/2002	FEREBEE RIVER	1
4/29/2002	FLAT (MUD BAY)	0
5/15/2002	FLAT (MUD BAY)	0
3/29/2002	HOBART/HOUGHTON	11
4/23/2002	HOBART/HOUGHTON	80
5/1/2002	HOBART/HOUGHTON	87
5/14/2002	HOBART/HOUGHTON	0
4/8/2002	KATZEHIN RIVER	61
4/18/2002	KATZEHIN RIVER	1
5/15/2002	KATZEHIN RIVER	0

Table A-5. Number of sea lions in water at eulachon and herring spawing sites during spring 2002. (cont'd.)

DATE	LOCATION	NUMBER OF SEA LIONS
4/29/2002	KATZEHIN RIVER	28
4/8/2002	LUTAK INLET	21
4/18/2002	LUTAK INLET	0
4/29/2002	LUTAK INLET	506
5/15/2002	LUTAK INLET	0
4/8/2002	MENDENHALL RIVER	0
4/29/2002	MENDENHALL RIVER	0
5/15/2002	MENDENHALL RIVER	0
4/10/2002	SEYMOUR CANAL	90
4/23/2002	SEYMOUR CANAL	111
5/1/2002	SEYMOUR CANAL	104
5/3/2002	SEYMOUR CANAL	221
5/14/2002	SEYMOUR CANAL	111
3/26/2002	SITKA SOUND	252
3/28/2002	SITKA SOUND	37
4/8/2002	SKAGWAY RIVER	1
4/18/2002	SKAGWAY RIVER	0
4/29/2002	SKAGWAY RIVER	2
5/15/2002	SKAGWAY RIVER	0
3/29/2002	SPEEL RIVER	0
4/9/2002	SPEEL RIVER	36
4/19/2002	SPEEL RIVER	22
5/14/2002	SPEEL RIVER	0
4/8/2002	TAIYA INLET	0
4/18/2002	TAIYA INLET	0
4/29/2002	TAIYA INLET	5
5/15/2002	TAIYA INLET	0
4/10/2002	TAKU INLET	235
4/19/2002	TAKU INLET	0
4/23/2002	TAKU INLET	2
4/9/2002	TENAKEE INLET	105
4/19/2002	TENAKEE INLET	84
5/3/2002	TENAKEE INLET	0
3/29/2002	WHITING RIVER	0
4/9/2002	WHITING RIVER	0
4/19/2002	WHITING RIVER	0
5/1/2002	WHITING RIVER	0